PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference TY04014PCT	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/JP2004/018328	International filing date *(day/month/year)* 02.12.2004	Priority date *(day/month/year)* 02.12.2003
International Patent Classification (IPC) or national classification and IPC G01S5/14		
Applicant TOYOTA JIDOSHA KABUSHIKI KAISHA et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 7 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 15 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the International application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the opinion
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
24.05.2005	13.12.2005
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Fanjul Caudevilla, J Telephone No. +49 89 2399-2533

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/JP2004/018328

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:

   ☐ international search (under Rules 12.3 and 23.1(b))
   ☐ publication of the international application (under Rule 12.4)
   ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1, 2, 11-39	as originally filed
3-10	received on 04.10.2005 with letter of 30.09.2005

Claims, Numbers

1-17	received on 04.10.2005 with letter of 30.09.2005

Drawings, Sheets

1/9-9/9	as originally filed

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   ☐ the description, pages
   ☐ the claims, Nos.
   ☐ the drawings, sheets/figs
   ☐ the sequence listing *(specify)*:
   ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   ☐ the description, pages
   ☐ the claims, Nos.
   ☐ the drawings, sheets/figs
   ☐ the sequence listing *(specify)*:
   ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/JP2004/018328

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-2,7-9,11-12,13,15,16
	No:	Claims	3-6,10,14,17
Inventive step (IS)	Yes:	Claims	7-9
	No:	Claims	1-6,10-16
Industrial applicability (IA)	Yes:	Claims	1-17
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

1. Reference is made to the following documents:

D1: US-A-5 903 236 (LAWRENCE ET AL) 11 May 1999 (1999-05-11)
D2: US-B1-6 373 432 (RABINOWITZ MATTHEW ET AL) 16 April 2002 (2002-04-16)
D3: US-A-6 127 968 (LU ET AL) 3 October 2000 (2000-10-03)

Matters related to Article 6 PCT

2. The presentation of four independent claims in the category "apparatus" (claims 1, 15, 16 and 17), and two independent claims in the category "method" (claims 13 and 14) gives rise to two objections under Article 6 PCT, i. e. lack of conciseness and lack of clarity. Said independent claims define the same inventive concept *(ambiguity estimation in kinematic GPS by associating data received by a reference station in a first duration with data received by a mobile station in a second duration)* by partially repeating subject-matter with different wording.

As to conciseness, it applies not only to individual claims but to the claims as a whole (Rule 6.1(a) PCT). The lack of clarity derives from the consideration that the prime function of the claims is to make clear what are the technical features of the matter for which protection is sought (cf. the first sentence of Article 6 PCT). In the present case, the understanding of those technical features is unduly hindered by the presence of multiple independent claims.

3. The feature in claims 1, 13, 15 and 16, that the listening period of data received by the mobile station (second duration) is **shorter** than the listening period of data received by the reference station (first duration), is an attempt to define the subject-matter in terms of the result to be achieved *(quickly resume of positioning when igniting a vehicle or after recovery from a cycle slip)*, which merely amounts to a statement of the underlying problem, without providing the technical features necessary for achieving this result.

4. Moreover, claims 1, 13, 15 and 16 do not contain features essential to the definition of the invention, as required by Article 6 PCT.

It is clear from the description on pages 21 - 25 and figure 5 that the inventive concept of the present application relies in combining data on the side of the mobile station at a certain time and data on the side of the reference station **prior to said certain time**, for calculating the integer ambiguity (in order to quickly start or resume positioning at the time of starting the vehicle). This feature is considered to be essential to the definition of the invention and should have been included in the claim. Said feature forms part of independent claims 14 and 17.

Matters related to Article 33 PCT

5. Furthermore, the above-mentioned lack of clarity notwithstanding, the subject-matter of claim 14 and 17 is not new in the sense of Article 33(2) PCT, and therefore the criteria of Article 33(1) PCT are not met.

D1, which is considered to be the closest prior art, discloses (figure 1 - 2; column 3, line 32 - column 5, line 39) a carrier phase GPS receiver that resolves the integer cycle ambiguity by using a prediction of the present reference phase value from the past reference phase information received by a data link receiver.

D1 discloses all the features of the carrier phase GPS positioning method and system of independent claims 14 and 17, namely:

acquiring a carrier phase accumulation value at one time on the mobile station side;

acquiring a plurality of carrier phase accumulation values at a plurality of times prior to the one tine on the reference station side;

associating the carrier phase accumulation values on the reference station side at the plural times, with a carrier phase accumulation value on the mobile station side at the one time, and estimating the integer ambiguity.

6. Furthermore, the above-mentioned lack of clarity notwithstanding, the subject-matter of claims 1, 13, 15 and 16 does not involve an inventive step in the sense of Article 33(3) PCT, and therefore the criteria of Article 33(1) PCT are not met.

D1 discloses a carrier phase GPS positioning method comprising the steps of acquiring a carrier phase accumulation value in a first duration on a reference station, acquiring a plurality of carrier phase accumulation values in a second duration on the mobile station side, and associating the so obtained carrier phase accumulation values.

The subject-matter of claims 1, 13, 15 and 16 differs from the disclosure of D1 merely in that "the second duration is shorter than the first duration". As previously stated in (3), this feature represents only an attempt to define the subject-matter in terms of the result to be achieved *(quickly resume of positioning when igniting a vehicle or after recovery from a cycle slip)*, which merely amounts to a statement of the underlying problem without providing the necessary features. The skilled person departing from the navigational device disclosed in D1 would choose a large number of reference samples in the base station order to arrive to an accurate value of predicted present reference phase. For this reason, the first duration would be larger than the second duration.

7. The features of the dependent claims 2 - 6 and 10 - 12 do not lead to a claim meeting the requirements of (Article 33(3) PCT), when combined to any claim to which they refer. They are either known from D1 - D3 or they are considered to be common design measures within the normal range of options envisaged by a person skilled in this art.

8. The technical solutions proposed in claims 7 - 9 are considered as involving an inventive step (Article 33(3) PCT). None of the prior art documents cited above discloses a carrier phase positioning device comprising a movement quantity detection unit, a second integer ambiguity estimation unit acting when the mobile station is at rest, and a third integer ambiguity estimation unit that is active while the

mobile station is moving, according to the features recited in said claims.

9. Other issues:

a) The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

b) Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D1 is not mentioned in the description, nor are these documents identified therein.

one has to calculate the variance of the position measured by the IMU alone when the electromagnetic wave is interrupted. In addition, if the electromagnetic wave is cut off for a long time, the search space expends accordingly, and it is difficult to re-determine the integer ambiguity in a short duration.

DISCLOSURE OF THE INVENTION

Accordingly, it is a general object of the present invention to solve the above problem of the related art.

A specific object of the present invention is to provide a carrier phase GPS positioning device capable of determining and re-determining an integer ambiguity quickly and precisely, a carrier phase GPS positioning method, a carrier phase GPS positioning system, and a reference station.

According to a first aspect of the present invention, there is provided a carrier phase GPS positioning device including a first integer ambiguity estimation unit that combines a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and a positioning unit that determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit.

According to the present invention, because

the integer ambiguity is estimated by using sampling data on the mobile station side in the second duration shorter than the first duration, the time up to estimation of the integer ambiguity is shortened. The carrier phase GPS positioning device of the present invention can be implemented as a mobile station receiving data from a reference station, a reference station receiving data from a mobile station, or a device receiving data from both the reference station and the mobile station.

Preferably, abnormal values are excluded from the first carrier phase accumulation data. In addition, when reception of an electromagnetic wave emitted from the satellite is temporarily interrupted, data prior to the interruption is excluded from the first carrier phase accumulation data.

Preferably, the plurality of first carrier phase accumulation data include a plurality of carrier phase accumulation data transmitted from the satellite at a first number of times in the first duration, and the second carrier phase accumulation data in the second duration include a plurality of carrier phase accumulation data transmitted from the satellite at a second number of times in the second duration, and here the second number is less than the first number. More preferably, the second number equals one. In the latter case, single epoch positioning is possible.

In addition, preferably, after the first integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using data measured on the mobile station side alone.

Therefore, the amount of communication data between the mobile station and the reference station is

greatly reduced after estimation of the integer ambiguity.

In addition, preferably, the carrier phase GPS positioning device further includes a movement quantity detection unit that detects a movement of the mobile station and a movement quantity of the mobile station when the mobile station is moving, a second integer ambiguity estimation unit that, when the mobile station is at rest, estimates the integer ambiguity included in the second carrier phase accumulation data. The estimation is made based on the first carrier phase accumulation data in the period when the mobile station is at rest, and a third integer ambiguity estimation unit that, while the mobile station is moving, estimates the integer ambiguity included in the second carrier phase accumulation data while taking movement detection results into consideration.

According to the present invention, the integer ambiguity estimation units carry out the estimation processing in parallel and independently from each other. Because integer ambiguities independent from each other are estimated, by comparing and investigating the integer ambiguities, an appropriate integer ambiguity can be obtained, and this can increase precision and reliability of the positioning.

As an embodiment, after the second integer ambiguity estimation unit or the third integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the second integer ambiguity estimation unit or the third integer ambiguity estimation unit instead of the integer ambiguity estimated by the first integer ambiguity estimation unit.

Further, if the mobile station is a vehicle having wheels, the movement quantity detection unit detects a movement of the vehicle based on a wheel speed sensor that detects a rotational speed of the wheels. When a slip ratio greater than a predetermined value is detected by at least the wheel speed sensor, the integer ambiguity estimation processing by the third integer ambiguity estimation unit is initialized, and the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit until the third integer ambiguity estimation unit estimates or re-estimates the integer ambiguity.

But when the integer ambiguity has been estimated by the second integer ambiguity estimation unit, the integer ambiguity estimated by the second integer ambiguity estimation unit may be used for determining the position of the mobile station.

Because the third integer ambiguity estimation unit takes movement quantity detection results into consideration, even when the mobile station is moving, it is possible to estimate the integer ambiguity at high precision.

In addition, preferably, when plural reference stations are present in a communication region, a reference station is selected which is able to communicate with more satellites in common with the satellite communicating with the mobile station, and the first carrier phase accumulation data related to the selected reference station are used. In addition, when there are plural reference stations able to communicate with the same number of satellites, a reference station is selected which has the highest minimum reception

strength of signals from the satellites. Further, when plural reference stations, which receive signals from plural common satellites and the signal reception strength of each of the common satellites exceeds a predetermined value, are present in a communication region, a reference station is selected which is closest to the mobile station, and the first carrier phase accumulation data related to the selected reference station are used.

Therefore, even the reference station changes along with the movement of the mobile station, reduction of the integer ambiguity estimation precision is preventable.

The carrier phase GPS positioning device of the above inventions may be installed in the navigation device of a vehicle acting as a mobile station, or other movable objects such as a working robot, a mobile phone, and a PDA, or alternatively, in a facility capable of bi-directional communication with the mobile station.

According to a second aspect of the present invention, there is provided a carrier phase GPS positioning method, including the steps of combining a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimating an integer ambiguity included in the second carrier phase accumulation data; and determining the position of the mobile station using the estimated integer ambiguity.

According to a third aspect of the present

invention, there is provided a carrier phase GPS positioning method including the steps of acquiring a carrier phase accumulation value at one time on the mobile station side; acquiring a plurality of carrier phase accumulation values at a plurality of times prior to the one time on the reference station side; combining the carrier phase accumulation values on the reference station side at the plural times, with a carrier phase accumulation value on the mobile station side at the one time, and estimating an integer ambiguity included in the carrier phase accumulation value of signals transmitted from the satellite received by the mobile station.

According to a fourth aspect of the present invention, there is provided a carrier phase GPS positioning system including a reference station that extracts a plurality of first carrier phase accumulation data in a first duration based on received data from a satellite; a carrier phase GPS positioning device including a first integer ambiguity estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; a positioning unit that determines the position of the mobile station using the estimated integer ambiguity; and a communication path that enables communication between the carrier phase GPS positioning device and the reference station.

According to a fifth aspect of the present invention, there is provided a reference station that extracts a plurality of first carrier phase accumulation data in a predetermined duration based on received data

from a satellite, and transmits the first carrier phase accumulation data to a carrier phase GPS positioning device including an estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the predetermined duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and a positioning unit that determines the position of the mobile station using the estimated integer ambiguity.

According to a sixth aspect of the present invention, there is provided a reference station including an acquisition unit that acquires a carrier phase accumulation value at one time on a mobile station side; an integer ambiguity estimation unit that combines a plurality of carrier phase accumulation values at a plurality of times prior to the one time on the reference station side with the carrier phase accumulation value on the mobile station side, and estimates an integer ambiguity included in the carrier phase accumulation value on the mobile station side; a positioning unit that determines the position of the mobile station using the integer ambiguity estimated by the integer ambiguity estimation unit; and a transmission unit that transmits the position detected by the positioning unit to the mobile station.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features, and advantages of the present invention will become more apparent from the following detailed description of preferred embodiments given with reference to the

accompanying drawings, in which:

FIG. 1 is a schematic view of a carrier phase GPS positioning device according to the present invention;

FIG. 2 is a diagram showing a configuration of the carrier phase GPS positioning device in FIG. 1;

FIG. 3 is a block diagram showing an embodiment of a carrier phase GPS positioning device 34 installed in the mobile station 30 according to the present invention;

FIG. 4 is a view illustrating the definitions of coordinate systems used in descriptions;

FIG. 5 is a flowchart illustrating the method of determining the integer ambiguity in the carrier phase GPS positioning device 34 according to the present embodiment;

FIG. 6 is a flowchart illustrating the optional processing subsequent to the routine in FIG. 5;

FIG. 7 is a flowchart illustrating an operation of determining the integer ambiguity by the time-series determination method of the related art, which is performed in parallel to the routine in FIG. 5

CLAIMS

1. (amended) A carrier phase GPS positioning device, comprising:

a first integer ambiguity estimation unit that combines a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and

a positioning unit that determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit.

2. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein abnormal values are excluded from the first carrier phase accumulation data.

3. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein when reception of an electromagnetic wave emitted from the satellite is temporarily interrupted, data prior to the interruption is excluded from the first carrier phase accumulation data.

4. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein

the plurality of first carrier phase accumulation data in the first duration includes a plurality of carrier phase accumulation data transmitted from the satellite at a first number of times in the first duration; and

the second carrier phase accumulation data in the second duration include a plurality of carrier phase accumulation data transmitted from the satellite at a second number of times in the second duration, said second number being less than the first number.

5. (amended) The carrier phase GPS positioning device as claimed in claim 4, wherein the second number equals one.

6. (original) The carrier phase GPS positioning device as claimed in claim 3, wherein after the first integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using data measured on the mobile station side alone.

7. (amended) The carrier phase GPS positioning device as claimed in claim 4, further comprising:

a movement quantity detection unit that detects a movement of the mobile station and a movement quantity of the mobile station when the mobile station is moving;

a second integer ambiguity estimation unit that, when the mobile station is at rest, estimates the integer ambiguity included in the second carrier phase accumulation data , said estimation being made based on the first carrier phase accumulation data and the second carrier phase accumulation data in the period when the mobile station is at rest; and

a third integer ambiguity estimation unit that, while the mobile station is moving, estimates the integer ambiguity included in the second carrier phase accumulation data while taking movement quantity detection

results into consideration.

8. (original) The carrier phase GPS positioning device as claimed in claim 7, wherein

after the second integer ambiguity estimation unit or the third integer ambiguity estimation unit estimates the integer ambiguity, the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the second integer ambiguity estimation unit or the third integer ambiguity estimation unit instead of the integer ambiguity estimated by the first integer ambiguity estimation unit.

9. (original) The carrier phase GPS positioning device as claimed in claim 7, wherein

the mobile station is a vehicle having wheels;

the movement quantity detection unit detects a movement of the vehicle based on a wheel speed sensor that detects a rotational speed of the wheels;

when a slip ratio greater than a predetermined value is detected by at least the wheel speed sensor, the integer ambiguity estimation processing by the third integer ambiguity estimation unit is initialized, and the positioning unit determines the position of the mobile station using the integer ambiguity estimated by the first integer ambiguity estimation unit until the third integer ambiguity estimation unit estimates or re-estimates the integer ambiguity.

10. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein

when a plurality of reference stations is present in a communication region, the reference station

is selected which is able to communicate with more satellites in common with the satellite communicating with the mobile station, and

the first carrier phase accumulation data related to the selected reference station is used.

11. (original) The carrier phase GPS positioning device as claimed in claim 10, wherein when there are plural of the reference stations able to communicate with the same number of the satellites, the reference station is selected which has the highest minimum reception strength of signals from the satellites.

12. (amended) The carrier phase GPS positioning device as claimed in claim 1, wherein

when a plurality of reference stations, which receives signals from a plurality of common satellites and the signal reception strength with each of the common satellites exceeds a predetermined value, is present in a communication region, the reference station is selected which is closest to the mobile station, and

the first carrier phase accumulation data related to the selected reference station is used.

13. (amended) A carrier phase GPS positioning method, comprising the steps of:

combining a plurality of first carrier phase accumulation data in a first duration extracted from data received from a satellite by a reference station at a fixed position, with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimating an integer ambiguity included in

the second carrier phase accumulation data; and

determining the position of the mobile station using the estimated integer ambiguity.

14. (amended) A carrier phase GPS positioning method, comprising the steps of:

acquiring a carrier phase accumulation value at one time on the mobile station side;

acquiring a plurality of carrier phase accumulation values at a plurality of times prior to the one time on the reference station side;

combining the carrier phase accumulation values on the reference station side at the plural times, with a carrier phase accumulation value on the mobile station side at the one time, and estimating an integer ambiguity included in the carrier phase accumulation value of signals transmitted from the satellite received by the mobile station.

15. (amended) A carrier phase GPS positioning system, comprising:

a reference station that extracts a plurality of first carrier phase accumulation data in a first duration based on received data from a satellite;

a carrier phase GPS positioning device including a first integer ambiguity estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the first duration, and estimates an integer ambiguity included in the second carrier phase accumulation data; and a positioning unit that determines the position of the mobile station using

the estimated integer ambiguity; and

a communication path that enables communication between the carrier phase GPS positioning device and the reference station.

16. (amended) A reference station that extracts a plurality of first carrier phase accumulation data in a predetermined duration based on received data from a satellite, and transmits the first carrier phase accumulation data to a carrier phase GPS positioning device including an estimation unit that combines the first carrier phase accumulation data with one or more second carrier phase accumulation data received from the satellite by a mobile station in a second duration shorter than the predetermined duration, and estimates an integer ambiguity included in the second carrier phase accumulation data ; and a positioning unit that determines the position of the mobile station using the estimated integer ambiguity.

17. (amended) A reference station, comprising:

an acquisition unit that acquires a carrier phase accumulation value at one time on a mobile station side;

an integer ambiguity estimation unit that combines a plurality of the carrier phase accumulation values at a plurality of times prior to the one time on the reference station side with the carrier phase accumulation value on the mobile station side, and estimates an integer ambiguity included in the carrier phase accumulation value on the mobile station side; and

a positioning unit that determines the position of the mobile station using the integer ambiguity

estimated by the integer ambiguity estimation unit; and

a transmission unit that transmits the position detected by the positioning unit to the mobile station.